OBSERVATIONS ON REARING *LUFFIA* SPP. (LEPIDOPTERA: PSYCHIDAE) UNDER CONTROLLED ENVIRONMENTAL CONDITIONS, WITH TAXONOMIC NOTES

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This note describes some observations made while rearing the two British "species" of moth belonging to the genus *Luffia* Tutt, namely *Luffia ferchaultella* (Stephens) and *L. lapidella* (Goeze). These observations were made during work to assess the suitability of *L. ferchaultella* for monitoring the toxicological effects of atmospheric pollution (Sims and Reynolds, 1999). They may contribute to the question of the uncertain taxonomic status of these moths.

The two moths shared many features of their life cycle, such as the numbers of ova laid and the duration to their hatching, the anatomical structure and behaviour of their larvae, pre-pupation behaviour, total duration of their life cycles, and the duration of life cycle stages. Furthermore, the number of larval instars was the same in both cases. These observations suggest that *L. ferchaultella* is a parthenogenetically reproducing form of *L. lapidella*.

However, differences between the two moths were noted. These included the size of ova, larvae, pupae and ovigerous females, the larval diets and sites chosen for pupation; and the mobility, "calling" behaviour and external anatomical structure of female moths. These observations support the argument that *L. ferchaultella* is a separate species from *L. lapidella*.

Taxonomic status

Hättenschwiler (1985) states that it is unclear what status should be afforded *L. ferchaultella*: whether it should be regarded as a species distinct from *L. lapidella* or as a form of that species. The moth representing *L. ferchaultella* reproduces parthenogenetically, producing only apterous female imagos. *L. lapidella* reproduces sexually, producing both winged males and apterous females. McDonogh (1939) proposed that the British distribution of *L. ferchaultella* is dictated by altitude and climatic factors, but Narbel-Hofstetter (1964) showed that the European distributions of these moths overlap in several areas (Fig. 1). Meyrick (1928) believed that populations of the sexually reproducing *lapidella* occasionally produced parthenogenetic populations of *ferchaultella* which die out over time. Seiler (1929) studied parthenogenetic and bisexually reproducing psychid moth material described as *Solenobia triquetrella* (Hübner). This material is now recognised as the parthenogenetic *Dahlica triquetrella* (Hübner) and the bisexual *D. inconspicuella* (Stainton), moths whose taxonomic status was equally as uncertain as that under consideration here. Seiler suggested that the bisexual moth (*inconspicuella*) is being replaced by the parthenogenetic moth (*triquetrella*). Tutt (1899) believed that *L. ferchaultella* and *L. lapidella* are distinct species, the view held by McDonogh (1941) who summarised these various positions thus:

Meyrick Type:

1) There must be continuous structural variation from the bisexual form to the most extreme parthenogenetic form.
2) There may be differences in the geographic distributions of the two forms.
3) Parthenogenetic females are likely to breed with males of the parent stock.

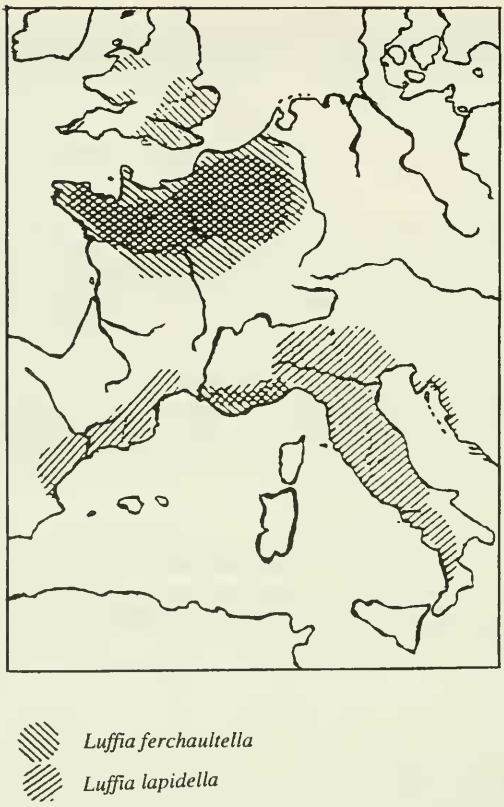


Fig. 1. The European distribution of *Luffia ferchaultella* and *L. lapidella* (adapted from Narbel-Hofstetter, 1964).

Seiler Type:
1) There should be no differences in structure between the two forms.
2) The geographic distributions will probably be identical.
3) Parthenogenetic females are likely to breed with males of the parent stock.

Tutt Type:
1) Structural variation between the two forms will almost certainly be discontinuous.
2) The geographic distributions will probably be different.
3) Parthenogenetic females may not be able to mate with males of the other form.

Henderickx (1987) describes finding pupal exuviae and winged male adults on the trunks of two oak trees near Mol, Belgium, in 1980 and 1986, among a parthogenetic population of *L. ferchaultella*. He compared their genitalia with those of male *L. lapidella* from Switzerland and Spain and found minor differences in the degree of chitination. However, he was unable to decide if the specimens from Mol represented *L. lapidella* or male examples of *ferchaultella*.

Rearing

Larvae of *L. ferchaultella* were collected from the trunks of deciduous trees, mostly oak and sycamore, in Oaken Grove near Henley-on-Thames, Buckinghamshire (SU769855) on 17.vii.1995. Larvae of *L. lapidella* were collected from lichens on rocks near Marazion, Cornwall (the UK locality where they were first discovered by Smith, 1983), on 21.ix.1995. Larvae of both moths were segregated and reared in transparent Perspex boxes under controlled conditions of temperature (mean 20.8, range 20.6 to 21.0°C) and photoperiod (14 hours light, 10 hours dark, no dawn/dusk period) using a Gallenkamp illuminated incubator.

Adult emergence

Luffia ferchaultella and *L. lapidella* are stated to emerge from their pupae in the early morning in nature (Hättenschwiler, *loc. cit.*). With both *L. ferchaultella* and *lapidella*, all emergences (a total of over 100 *ferchaultella*, all females, and around 40 *lapidella*, evenly split between males and females) occurred within the first hour or two of the light cycle. Immediately following emergence, the *ferchaultella* females commenced oviposition in the old pupal exuviae within their larval cases. However, with female *lapidella*, pairing was found to be an essential prerequisite to oviposition. Prior to mating, virgin *lapidella* females were observed to "call" for a mate in the manner described by McDonogh (1941). On introduction of a male to a female, pairing occurred almost instantly and lasted from 30 seconds to one minute. Pairing one male with several females was not attempted. Spontaneous pairings were avoided as pupae were isolated prior to emergence and it was found that no eggs, fertile or otherwise, were laid by virgin females of *lapidella*. This calling behaviour was never seen with *ferchaultella*. Pairings between female *ferchaultella* and male *lapidella* were attempted on two occasions, without success. The female moths did not adopt calling postures and the males showed no interest in them. This observation supports the "Tutt Type" proposed by McDonogh (1941).

Newly emerged *lapidella* females were three or four times larger than fresh *ferchaultella* females. These comparisons were made immediately after eclosion, as once oviposition commenced the adults shrank rapidly as the ova left their abdomens. Females of both *lapidella* and *ferchaultella* did not voluntarily leave the surface of their larval cases after eclosion, and if physically removed to even a short distance were unable to return to them. However, *lapidella* females were more active than those of *ferchaultella*, spontaneously moving around on their cases while calling for a mate.

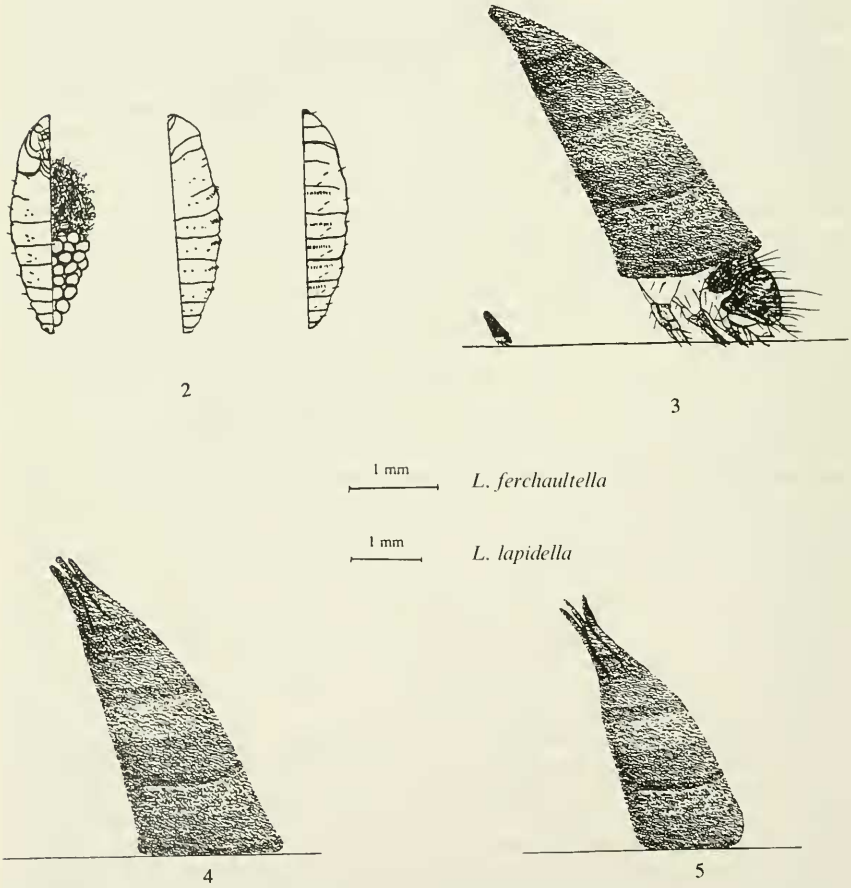
After oviposition, females of both "species" survived for two or three days, eventually shrivelling and remaining attached to their cases or falling from them. Male *lapidella* survived for a similar period.

The published descriptions of the external anatomy of female *lapidella* and *ferchaultella* differ in that female examples of *lapidella* have seven to nine antennal segments and three to four tarsal segments, while female *ferchaultella* have six to eight antennal segments and one to three tarsal segments (Hättenschwiler, *loc. cit.*). This was the case for females reared during this project, another point in favour of the "Tutt Type". However, McDonogh (1943) states that the adult morphology of *L. ferchaultella*, in terms of antennal and tarsal segment number, was influenced by the laboratory conditions under which he held larvae. By rearing larvae of both "species" under controlled environmental conditions, any environmentally induced morphological differences should be eliminated.

McDonogh (1941) illustrated the genitalia of female *L. lapidella* and *L. ferchaultella* and found no obvious differences. These structures were compared using material reared during this work, with the same outcome, except that *lapidella* material was somewhat larger than *ferchaultella*.

Oviposition

With both "species", oviposition was completed within 24 hours and usually by the end of the light cycle. On average, between 30 and 40 ova were produced by females of each "species"; in each case the ovum had a soft chorion without obvious sculpturing and was of an opaque grey/yellow colour when first laid. The only



Figs 2–5. Early stages of *Luffia* spp. 2. Pupa showing position of ova and hair scales. 3. First instar and fully grown larva (fifth instar) showing banding on case due to different coloured lichens/algae. 4. Pre-pupation larval case with valves cut for eclosion of adult. 5. Larval case shrunken by contraction of reinforcing silk, to form a pupation chamber.

difference appeared to be one of size, *lapidella* ova being noticeably larger than those of *ferchaultella*.

For both "species", the ova were packed into the rear three-quarters of the pupal exuviae, the anterior portion of the exuvia being filled with hair scales from the female moths' anal tuft (Fig. 2). Batches of *ferchaultella* ova collected from the wild have been observed to be predated by thrips and mites, so the presence of these hair scales may afford the ova some protection by hindering the access of such predators.

With both "species", four or five days before eclosion of the larvae, their darkening head capsules became visible through the chorion and subsequently through the wall of the pupal exuviae. Hatching of the ova at this temperature (20°C) occurred at around 30 days for both "species", the young larvae immediately building silk-lined cases coated with lichen and algae.

Larvae

The larvae of both "species" passed through five instars, separated on the basis of the widths of their head capsules, and were full grown by about 60 days (20°C). No diapause occurred, although with *ferchaultella* the third instar lasted approximately twice as long as any of the others. With larvae of *lapidella*, the third instar, although less protracted than that of *ferchaultella*, also lasted longer than any of the other four. This indicates that the third instar may be the stage at which overwintering occurs in the natural state.

The larvae of both moths enlarged their cases as they grew, preserving a record of the material they had been feeding on in the form of differently coloured bands of algae and lichen laid down on the exterior of their cases (Fig. 3). Larvae of both moths accepted algae (*Diplococcus* sp.) and lichen (*Lecanora conizaeoides*) growing on wood, and encrusting lichen (*Parmelia glabratula*) growing on rocks. However, rearing *lapidella* larvae was successful only if lichens from rocks were offered, while larvae of *ferchaultella* preferred lichens and algae growing on wood. First instar larvae of *lapidella* offered lichen and algae on wood failed to produce adults, most dying in their third instar. First instar larvae of *ferchaultella* offered rock lichen also died before reaching maturity. Both were successfully reared on their preferred diets, lichen and algae on wood for *ferchaultella*, and lichen on rocks for *lapidella*.

Larvae of both "species" were identical in colour and darkened noticeably on entering their third instar. Prior to this they were creamy white and opaque with a plain darkened prothoracic plate. On assuming their third instar the chitinised plate on the prothoracic segment acquired a pale grey triangular marking in the dorsal position. This marking and the plate were of similar colour and shape for both "species", and persisted to the end of the final instar. The structure of the larval head capsules and true walking legs was compared microscopically. There were no obvious differences in chaetotaxy or in the shape of the mandibles, antennae or other chitinised parts of comparable instars. The pale ocelli present on the sides of the head capsules were also identical. However, a major point of difference was that the cases of final instar *lapidella* larvae were approximately twice the size of those of full-grown *ferchaultella* larvae, and the larvae themselves were similarly larger.

The importance of moisture to the successful rearing of both "species" was realised at an early stage. Larval growth was maximised if the substrate was sprayed with a fine mist of distilled water twice a week. On spraying, the larvae became very active and were observed to search for droplets of water which they drank once located. Drinking proceeded as a series of ingestions rather than a steady intake,

characterised by a pulsed decrease in droplet size. Larvae imbibed several small droplets or part of a larger one, the amount ingested increasing as the larvae grew.

The literature suggests that larvae of both "species" may be found feeding on lichens and algae growing on rocks and wood in nature. As far as can be ascertained this is not the case: all adults resulting from larvae collected from lichen on sunny exposed rocks in Cornwall corresponded to *lapidella*, while larvae collected from shaded damper tree trunks in Buckinghamshire produced adults typical of *ferchaultella*. This distribution supports McDonoghs "Tutt Type". However, in culture the larvae of both moths behaved similarly, feeding exposed on their substrates but tending to shelter out of direct illumination when not feeding, indicating no preference for habitat type. *Luffia lapidella* is stated to prefer dry sunny habitats while *ferchaultella* favours shady situations with high humidity (Hättenschwiler, *loc. cit.*). This was the case with the pupation sites chosen by cultured larvae.

Pre-pupation behaviour

Prior to pupation the larvae of both "species" loosely affixed their cases to the substrate before turning round within the case and using their mandibles to cut three or four evenly spaced longitudinal slits in its anal end (Fig. 4). This procedure commenced at the rear opening and the cut proceeded towards the fixed "head end" of the case. These cuts were around one fifth to one sixth of the length of the case and formed "valves' to facilitate the subsequent emergence of the imago. The larvae then reverted to their original head-down position, detached their cases from the substrate and wandered until they found suitable sites for pupation. Here their behaviour differed significantly. With *ferchaultella*, such sites were usually within a crevice or crack in the surface of tree bark and shaded from direct illumination. Larvae of *lapidella* affixed their cases prior to pupation in exposed situations in full illumination. Once the pupation site had been selected, the larvae of both "species" affixed their cases firmly to the substrate with white silk. They then inverted their position so that they were again facing the recently prepared exit at the free end of the case. The cases were then reinforced by an additional lining of white silk, forming a pupation chamber. Pupation occurred within these chambers, the additional silk lining having shrunk such that the cases became bottle-shaped (Fig. 5).

Pupae

The pupal stage was of similar duration for both "species", eclosion of the adults occurring after about 20 days at this temperature. There appeared to be no visible differences in the structure of female pupae between the two "species", (but see Figs 28 and 29 in McDonogh, 1941). However, only pupal exuviae were examined, making comparison of the headplates and leg sheaths difficult as these were distorted or lost on eclosion of the adults.

Duration of the life cycles

In nature both *ferchaultella* and *lapidella* are univoltine, but under these environmental conditions their life cycles were reduced to four months, ova to ova (Fig. 6). In both cases the stages in the life cycles were of similar duration.

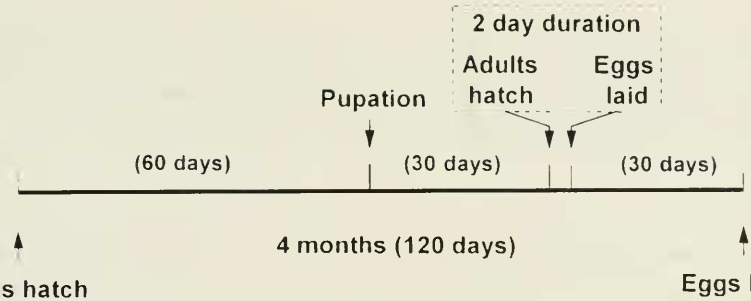


Fig. 6. Duration of life cycles for both moths under controlled environmental conditions.

Distribution

As far as is known, in the UK *L. lapidella* is restricted to the area around Marazion in Cornwall (Smith, *loc. cit.*) and to the Channel Isles, where it occurs together with *L. ferchaultella* (McDonogh, 1941). The ability of *lapidella* to survive the rigours of winter away from the mild maritime climates of the Cornish coast and the Channel Isles was investigated by placing ten newly hatched (hence parasite free), first instar *lapidella* larvae on an isolated lichen-encrusted rock in Buckinghamshire in June 1995. Four of these survived the winter of 1995/96, an unusually long and cold one compared with those experienced previously in this area. These survivors were removed in April 1996 and subsequently reared under the controlled environmental conditions already described. From these, one male and one female duly emerged, both typical examples of *lapidella*. This 20% survival shows that climate may not be the controlling factor in the distribution of *lapidella*. This is supported by a male example, probably of *lapidella*, reared from a case found near Saffron Walden, Essex (Emmet, 1998).

Parasitism

Many parasitic Hymenoptera were reared from larvae of both "species" collected from the wild. These have been examined by Dr M. R. Shaw at the National Museums of Scotland, Edinburgh. One species, *Lissonota luffiator* Aubert, appears to have an interesting biology. This solitary endoparasitic ichneumon was obtained only from larvae of *ferchaultella*, though this does not necessarily mean that *lapidella* larvae are immune from its attack. All of the 20 or so imagos of this parasite that emerged were females. Furthermore, an infected host larva appears to have its life cycle altered by the presence of the parasite in one of two ways. Either the growth of an affected larva is greatly accelerated when compared with that of its healthy peers, or pupation of the host in summer is prevented by the parasite, the host larva entering a second winter. Either of these strategies would account for the presence of abnormally large *ferchaultella* larvae overwintering on trees at the same time as smaller second or third instar larvae. If collected during November or December and kept indoors, these large, active and apparently healthy larvae, bearing a remarkable resemblance to larvae of *lapidella* due to their size, invariably produce females of this parasitic wasp. Many of these large overwintering larvae were collected in the hope of obtaining *lapidella* from areas outside its known UK distribution, but all produced parasitic wasps of this species.

Discussion

This project has demonstrated that the "species" we know as *L. lapidella* can survive in areas of the UK outside its Cornish range, while the record of a male from Essex indicates that *L. lapidella* may either be extending its range in the UK or that it is present at a low density over a wider area than is currently known.

The observations made during the rearing of these moths may be summarised thus:

- No differences were observed between *lapidella* and *ferchaultella* as regards oviposition. The number of ova laid, their positioning within the pupal exuvia, surface structure, colour and period to hatching were the same for both "species".
- Anatomically, larvae of *lapidella* and *ferchaultella* appeared identical. Their chitinised structures and chaetotaxy were similar. Furthermore, they behaved similarly in the culture vessels and had the same number of instars, with the third instar being the point at which their colour darkened. This instar was protracted in both cases.
- The procedures for preparation of their cases prior to pupation were the same.
- Female pupal exuviae of both "species" appeared to have similar anatomical structures and eclosion of the adults occurred at the same point in the light cycle.
- The total duration of their artificially shortened life cycles was similar under these controlled conditions, as was the duration of the individual life cycle stages.

These observations suggest that *L. ferchaultella* is a form of *L. lapidella*.

Apart from the obvious difference in their modes of reproduction, the main differences between these "species" were the larger size of *lapidella* ova, larvae and pupae, their preferred larval diets, the different pupation sites chosen, the larger size of *lapidella* females, their greater mobility and calling behaviour, and differences in the external anatomy of female imagos. It is also possible that these "species" are host to different assemblages of parasites, but this may be due to the geographic ranges of the parasites and needs further investigation before any definitive statement can be made. These observations suggest that *L. ferchaultella* and *L. lapidella* are distinct species.

It is clear that the taxonomic status of these moths cannot be determined on the basis of these observations alone. Taken as a whole, the weight of evidence tends to support McDonogh's "Tutt Type", i.e. that *lapidella* and *ferchaultella* are distinct species. However, this question will probably only be resolved by the application of biochemical techniques as outlined by Cook (1996), for example gel electrophoresis and/or chromosomal studies.

Populations of these moths were not adversely affected by the removal of larvae for this work, as twice the number of larvae removed were returned (parasite and disease free as they had been reared under laboratory conditions) to their original localities during the winter of 1996. Great care was taken to avoid mixing the stocks prior to their release.

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SHORT COMMUNICATION

***Crossocerus vagabundus* (Panzer) (Hymenoptera: Sphecidae) in Wales**—This is the rarest of our four black and yellow *Crossocerus* species, holding RDB1 status. In the past this species was widespread, if local, in the south of England and had been recorded from 25 vice-counties (Falk, 1991). It has not been reported as occurring in Wales. In 1953 it was recorded from Parley Heath, Dorset and was not recorded again until recently, when the species was found at a number of sites in Hampshire. The species is associated with damp lushly vegetated areas where it preys upon craneflies. Nesting occurs in dead wood, often in the galleries of beetle larvae (Falk, 1991). On the 7.viii.1998, while collecting in birch scrub along the margins of Crymlyn Bog (SS687943), Glamorgan, specimens of *Crossocerus dimidiatus* (Fab.) and *C. quadrimaculatus* (Fab.) were collected. Whilst determining the specimens taken, a single male *C. vagabundus* (Panzer) was found amongst the *C. quadrimaculatus*. Superficially to the naked eye it looked very like *C. quadrimaculatus* and certainly was not noticed to be anything other than that species in the field.—P. M. PAVETT, Department of Biodiversity and Systematic Biology, National Museum and Galleries of Wales, Cathays Park, Cardiff CF1 3NP.

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